Chapter 3: Performance and Optimization of Agricultural Best Management Practices

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SUMMARY

Nutrient-rich discharges from the Everglades Agricultural Area (EAA) have been identified as contributors to the enrichment of the Everglades and are the primary focus of the Everglades Regulatory Program and the Everglades Construction Project (ECP). Substantial efforts in BMP implementation, research, and education have been directed at reducing phosphorus (P) loading from the EAA basin as part of the Everglades Program. These combined efforts are responsible for an appreciable reduction in the loads and concentrations of total phosphorus (TP) attributable to the EAA basin and conveyed to the Everglades Protection Area (EPA).

The objective of this chapter is to provide an update on the effectiveness of Best Management Practices (BMPs), as demonstrated by the implementation of the Everglades Regulatory Program and research in the EAA basin. Information includes the current year's data as well as recommendations and conclusions, which are similar to those presented in previous years.

The overall effectiveness of BMPs is best demonstrated by the measured phosphorus load reduction in the EAA basin since BMPs were implemented, compared to a 10-year, pre-BMP base period. The BMP Regulatory Program in the EAA basin, mandated by State of Florida legislation, is one aspect of the South Florida Water Management District's (SFWMD's or District's) Everglades Restoration Program. The goal of the BMP regulatory program is to achieve a 25-percent reduction in phosphorus load from the EAA basin. This reduction is determined by comparing phosphorus discharges from District structures at the end of each 12-month water year (May 1 through April 30) to the pre-BMP base period of October 1, 1978 through September 30, 1988. The base period phosphorus discharges are adjusted for the differences in the amount and distribution of rainfall for the current period. The rule requires the District to evaluate the data collected to assess the general trend in phosphorus load reduction, determine whether the EAA basin is in compliance with the phosphorus load reduction requirement, and publish the results annually. The EAA basin has been in compliance since the first full year of BMP implementation (Water Year 1996).

The phosphorus load discharged from the EAA basin for Water Year 2002 (WY02) is:

WY02 (measured with BMPs in place)	101 tons
Base period (predicted with WY02 adjusted rainfall)	227 tons

The relative difference between the WY02 measured tonnage and the predicted base period tonnage (adjusted for rainfall) indicates a 55 percent reduction in total phosphorus load. In analyzing data trends, the three-year trend ending in WY02 equates to a 59 percent reduction of the phosphorus load from the EAA basin (with a three-year flow-weighted mean concentration of 92 parts per billion [ppb]). The latest load reduction continues the trend of consistently exceeding the 25 percent load reduction requirement. This load reduction is specific to the EAA and does not account for all phosphorus loads entering the Everglades from other sources, including Lake Okeechobee releases (environmental, urban water supply, and regulatory), 298 diversions, C-139, C11 West, L-28, Feeder Canal basin, ACME basin B, North Springs Improvement District, North New River Canal basin, C-111, and Stormwater Treatment Areas (STAs). These other sources and their relative contributions are discussed further in chapters 1 and 8B of the *2003 Everglades Consolidated Report* (*2003 ECR*).

This chapter discusses the methodology for the EAA basin calculations and includes a summary of the permit-level data from individual permittee-operated discharge structures within the EAA basin. These permit-level data (provided in **Appendix 3-1**) will only be used for Chapter 40E-63, Florida Administrative Code (F.A.C.), compliance determination if the EAA basin does not meet the 25 percent P load reduction requirement. A direct statistical relationship between the permit level loads and the EAA basin level loads has been difficult to establish because of the recycling effect caused by EAA basin canal water and individual farm discharges being drawn back into the farms for irrigation or freeze protection. Additionally, there are several factors affecting P load at the farm level, making it difficult to make comparisons or draw conclusions on differences in the level of performance between farms. However, these data are used to optimize BMPs by making relative comparisons between water years for the same farm. These data are also used to determine credits toward the Everglades Agricultural Privilege Tax mandated by the Everglades Forever Act (EFA). As of WY02, the EAA basin has earned enough credits to allow reduction of the Everglades agricultural privilege tax to the minimum annual rate of $24.89 per acre through water year 2012. A summary of the Everglades agricultural privilege tax data is provided in **Appendix 3-1**.

In addition to the Everglades Regulatory Program, the EFA and Chapter 40E-63, F.A.C., require EAA landowners, through an organization called the EAA Everglades Protection District (EAA-EPD), to sponsor a program of BMP research, testing, and implementation to monitor the efficacy of the established BMPs. This has been accomplished through the University of Florida Institute of Food and Agricultural Sciences (IFAS) EAA BMP farm-scale study sponsored by the EAA-EPD and the Florida Department of Environmental Protection (FDEP). In addition to collecting data to assess the effectiveness of BMPs, the IFAS research in the EAA includes identification of short-term and long-term affects of BMPs on soils and crops; evaluation of specific conductance and total dissolved P in farm discharges; and evaluation of particulate matter in farm and EAA drainage canals.

IFAS results continue to confirm that BMPs are highly effective in reducing P loads discharged from participating farms. One major component of the IFAS research, the study of particulate P transport, has concluded that the primary source of particulate P exported in the EAA is from biological growth in the main farm canal system. IFAS concludes that additional reductions in P loading can only be achieved by continuing to analyze the mechanisms that contribute to BMP efficacy and optimization. Another IFAS research component includes a lysimeter study (results to be released in the spring of 2003), conducted to demonstrate short- and long-term effects of BMPs on soils and crops. There is also on-going analysis of specific conductance levels in the EAA, however, there is insufficient data at this time to draw conclusions concerning the original hypothesis that agricultural practices, changes in hydrology, and connate seawater are factors contributing to elevated levels of specific conductance. The latter part of this chapter provides an update on the various components of IFAS research in the EAA since the *2002 Everglades Consolidated Report*.

The combined efforts from the Everglades Regulatory Program in the EAA and the cooperative program of research, implementation, and testing of BMPs over the past several years coincide with appreciable reductions in TP concentrations and load attributable to the EAA basin that are ultimately conveyed to the Everglades. The regulatory program and IFAS research data have consistently confirmed that existing BMPs are reducing P loading from the EAA basin. This is evident in the fact that the EAA basin has consistently exceeded the 25 percent load reduction requirement since BMPs were implemented; however, it is still unclear whether further P load reductions at the farm level will result in further impacts on the overall EAA basin P load. It is recommended that the research, monitoring, and education efforts continue in an effort to gain a better understanding of optimization techniques for BMPs and to apply “lessons learned” to individual permittees, as well as to other regions that discharge to the Everglades through aggressive outreach programs to expand the BMP message.

INTRODUCTION

A significant component of the EFA establishes both interim and long-term water quality goals to ultimately achieve restoration and protection of the Everglades. As mandated by the EFA, the long-term phosphorus (P) concentration will be set by the State of Florida Environmental Regulatory Commission (ERC) based on available research, or will default to 10 parts per billion (ppb). The long-term goal is to combine point source, basin-level, and regional solutions in a system-wide approach to ensure that all waters discharged to the Everglades are achieving water quality goals. The interim design goal encompasses current activities, the Everglades Regulatory Program, and the Everglades Construction Project (ECP) to achieve an annual average P discharge concentration of 50 ppb for the final discharge from the ECP (Stormwater Treatment Area [STA] outflow). Surface water tributary sources to the ECP (STA inflows) include the discharges from the EAA basin, Chapter 298 water control district diversions, the C-139 basin, and Lake Okeechobee normal releases (environmental, water supply, and regulatory). See the Chapter 1, Figure 1-1 location map for more information.

Agriculture is the predominant land use in both the EAA and C-139 basins. Nutrient-rich water from both areas contributes to Everglades enrichment and is the primary focus of the Everglades Regulatory Program and the ECP. The Everglades Regulatory Program provides for the implementation of BMPs as point source treatment upstream of the STAs. The STA designs are based on the premise that the EAA basin discharges have a 25 percent reduction and the C-139 basin not exceed the historic P load when compared to the pre-BMP base period of October 1, 1978 through September 30, 1988 (when adjusted proportionately for rainfall).

The EAA basin is located south of Lake Okeechobee within Eastern Hendry and Western Palm Beach counties and encompasses an area of approximately 1,122 square miles of highly productive agricultural land comprised of rich organic peat or muck soils (**Figure 3-1**). The area is considered one of Florida’s most important agricultural regions, approximately 77 percent of which is devoted to agricultural production. The major crops in the EAA basin include sugar cane, vegetables, and sod, with secondary crops in rice and citrus. The EAA basin ultimately discharges to the Everglades through STA-1W, STA-2, STA-6, and eventually will discharge through STA-1E and STA-3/4, once construction is complete. The BMP Regulatory Program was

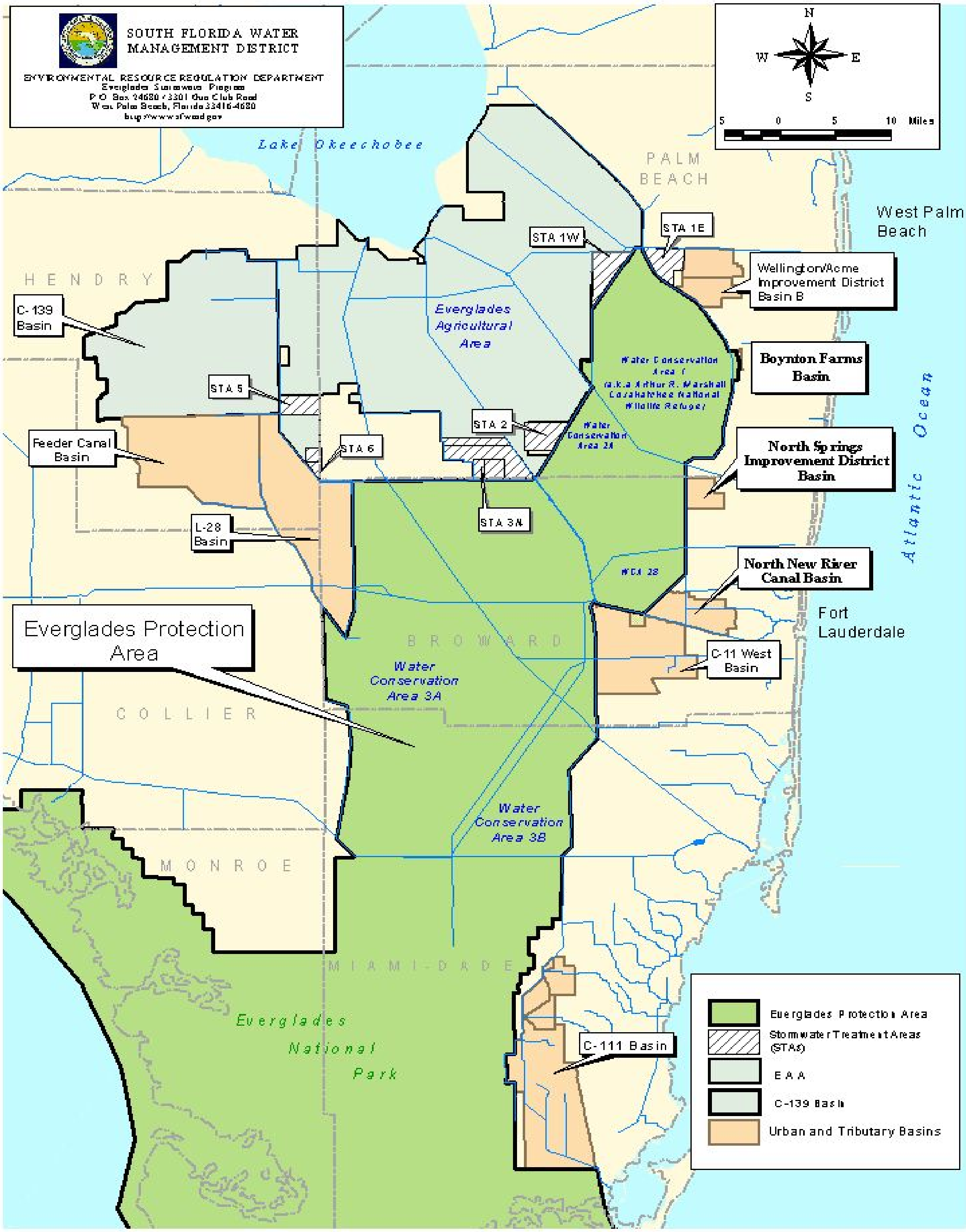

Figure 3-1. The Everglades Agricultural Area (EAA)

initiated in the EAA in 1992. Coincident with BMP implementation by EAA basin landowners, the annual P load from the EAA basin has consistently been reduced by levels greater than that required by rule.

The C-139 basin is located southwest of Lake Okeechobee within Eastern Hendry County adjacent to the EAA basin (**Figure 3-1**). The C-139 basin ultimately discharges to the Everglades through STA-5. Amendments to Chapter 40E-63, F.A.C., effective January 24, 2002, require implementation of a BMP regulatory program in the C-139 basin in accordance with the EFA. The rule establishes a compliance methodology similar to that of the EAA basin (disregarding the 25 percent load reduction criteria) to determine the annual average phosphorus load limitation for the C-139 basin and a plan for BMP implementation to minimize P in offsite discharges. The amendments require basin landowners to obtain permits for BMP plans and report annually to the District on the status of BMP implementation. WY03 will be the first year for compliance determination in the C-139 basin. These efforts are intended to ensure that discharges from the C-139 meet established P load limits and ultimately reduce the nutrient loading contribution to the northern Everglades. Until BMPs are fully implemented in the C-139 basin, evaluation of BMP effectiveness will focus solely on the EAA basin.

The implementation of BMPs is the cornerstone of P source control on the farms. BMPs have been implemented in the EAA basin for seven complete compliance years and have proven successful. Additionally, ongoing BMP research initiated as early as 1992 in the EAA basin continues to confirm varying degrees of effectiveness in TP reduction through the implementation of combinations of water management practices, fertilizer application control practices, and particulate matter control practices. This chapter presents a summary of the Everglades Regulatory Program, describes the BMPs implemented, explains the compliance methodology, updates data summaries with WY02 EAA basin-level and permit-level monitoring results, and summarizes the findings of the on-going IFAS research on BMPs in the EAA.

UPDATE ON EVERGLADES REGULATORY PROGRAM

The Everglades Regulatory Program, Chapter 40E-63, F.A.C. ("Rule 40E-63"), states that lands in the EAA that release water that ultimately makes use of, connects to, releases to, or discharges to the Works of the District (WOD) within the Everglades require a permit. Rule 40E-63 permits approve a BMP Plan and a Water Quality Monitoring Plan for each sub-basin.

Currently, there are a total of 33 EAA basin Everglades WOD permits, including approximately 210 sub-basins and 300 privately owned water control structures discharging into the District canals in the EAA encompassing an area of approximately 500,000 acres (**Figure 3-2**). The regulated area is described by rule and thus remains static. The area represented by a single permit varies substantially, anywhere between 120 and 92,000 acres. There are annual differences in the total permitted acreage, typically the result of acreage being removed from permits as areas are converted from agricultural production to Stormwater Treatment Areas.

The minimum target for BMP plan development in the EAA basin was established as twenty-five BMP equivalents, or points (**Table 3-1**). By using the BMP-equivalents approach, each permittee has flexibility to develop a BMP plan that is best suited for site-specific soil types, hydrology, and crop conditions. For each proposed BMP, the permittee must consider how the BMP will be implemented, how the staff responsible for BMP implementation will be trained, and how BMP implementation will be documented.

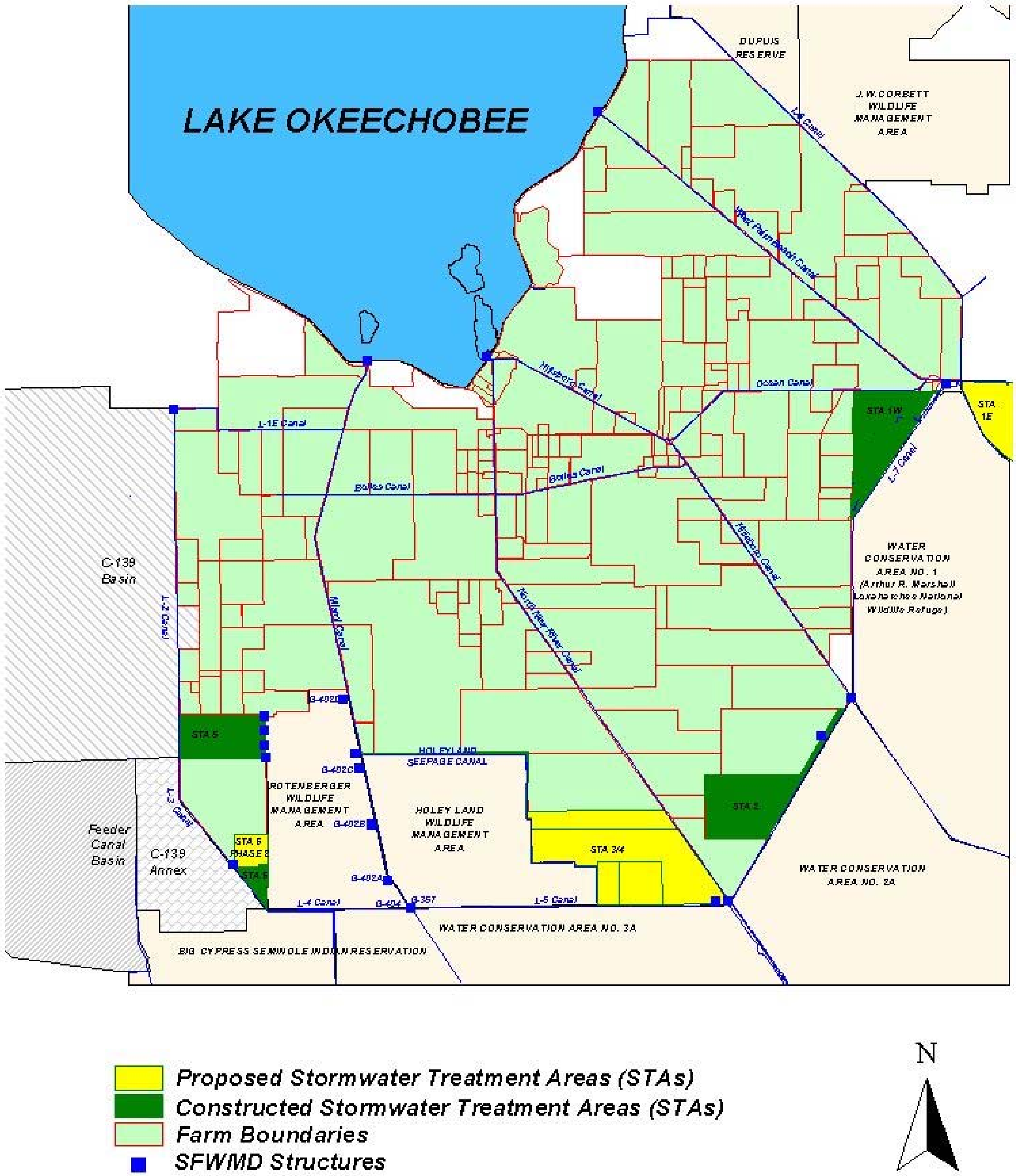

Figure 3-2. The Everglades Agricultural Area (EAA) basin

TABLE 3-1. Best Management Practices summary and "BMP equivalent" points

BMP	PTS	DESCRIPTION
WATER MANAGEMENT PRACTICES		MINIMIZES THE VOLUME OF OFF-SITE DISCHARGES
½ Inch Water Detention 1 Inch Water Detention	5 10	Delay pumping based on rain gage measurements. Detention (in farm canals and soil profile) measured on a per event basis – rainfall vs. runoff.
Improved Infrastructure	5	Water table management plan; controlling levels in canals and field ditches using internal water control structures, fallow fields, aquatic cover crop fields, prolonged crop flood; effective irrigation and discharge plans.
Other	tbd	e.g. Properly constructed and maintained storage system; greater detention with water management plan having target water table levels and structure operating procedures; monitored water table.
NUTRIENT CONTROL PRACTICES		MINIMIZES THE MOVEMENT OF NUTRIENTS OFF-SITE * Limited Applicability
Fertilizer Application Control	2 ½	Uniform and controlled boundary fertilizer application (e.g. banding at the root zone; pneumatic controlled-edge application such as AIRMAX); calibrated application equipment; setbacks from canals.
Fertilizer Spill Prevention	2 ½	Formal spill prevention protocols (handling, transfer, education).
Soil Testing	5	Avoid excess application by determining P requirements of soil.
Plant Tissue Analysis	2 ½	Avoid excess application by determining P requirements of plant.
Split P Application*	5	Applying P proportionately at various times during the growing season. Total application not exceeding recommendation.
Slow Release P Fertilizer*	5	Applying specially treated fertilizer that breaks down slowly thus releasing P to the plant over time.
PARTICULATE MATTER AND SEDIMENT CONTROLS		MINIMIZES THE MOVEMENT OF PARTICULATE MATTER AND SEDIMENTS OFF-SITE (Each consistently implemented across the entire basin acreage.)
Any 2 Any 4 Any 6	2 ½ 5 10	• leveling fields • cover crops • ditch bank berm • raised culvert bottoms • sediment sumps in canals • stabilized ditch banks • sediment sumps in field ditches • aquatic plant management • canal/ditch cleaning program • debris barriers at outfall • slow drainage velocity near pumps • sediment sump upstream of drainage structure
PASTURE MANAGEMENT		PLAN FOR ON-FARM OPERATION AND MANAGEMENT PRACTICES
PASTURE MANAGEMENT	5	• reduce cattle waste nutrients in discharges by "hot spot" management, i.e. plans for placement of drinking water, feed and supplements, cowpens and shade. • low cattle density
OTHER BMPS		OTHER PRACTICES PROPOSED
Urban Xeriscape	5	Use of plants that require less water and fertilizer.
Det. Pond Littoral Zone	5	Vegetative filtering area for on-site stormwater runoff.
Other BMP Proposed	tbd	BMP proposed by permittee and accepted by SFWMD.

Post-permit compliance activities include verification of the implementation of the approved BMP plans by two methods: (1) annual submittal of BMP implementation reports by the permittee, and (2) in-field visual observations and review of documentation. The goal is to conduct onsite verifications annually, but this can vary depending on circumstances. Onsite verifications allow District staff to discuss BMP strategies and optimization of current BMP practices with permittees. The BMP site verifications conducted thus far indicate that permittees have implemented their respective BMP plans and are taking a proactive approach to reviewing and voluntarily improving their plans, where possible.

COMPLIANCE DETERMINATION

Within the EAA basin, monitoring is performed at two levels:

(1) EAA basin-level monitoring by the District

(2) Individual sub-basin or farm-level monitoring by the owner/operator of private water control structures discharging within the EAA basin.

The primary means used to determine the success of the Rule 40E-63 program is through District data collection and analysis of water quality monitoring conducted at the EAA basin level. Discharge P concentrations and quantity are recorded at all inflow and outflow points, including: S-2/351 complex, S-3/354 Complex, S-352, S-5A complex, S-6, S-7, S-150, S-8, G-136, G-200, G-328, G-344A, G-344B, G-344C, G-344D, G-349B, G-350B, G-600, G-410, G-402A, G-402B, G-402C, G-402D, G404, G-357, EBPS3, and ESPS2 (**Figure 3-2**). The TP levels measured at these structures collectively determine primary compliance for all EAA WOD permits. For primary compliance, the EAA basin must demonstrate a 25-percent reduction in load annually compared to the pre-BMP base period.

A secondary method of program compliance measurement is through individual sub-basin ("permit level" or "farm level") water quality monitoring conducted by the permittee. Permit-level monitoring will be used only for compliance determinations if the EAA basin does not meet the 25-percent load reduction requirement. Permit-level data are also used to determine credits toward the Everglades Agricultural Privilege Tax mandated by the EFA (Section 373.4592(6), Florida Statutes). See **Appendix 3-1**, **Table 2**, for a summary table of the tax credits. Permittee water quality monitoring results are not used to calculate the TP reduction at the EAA basin level.

EAA BASIN-LEVEL MONITORING RESULTS

Since the implementation of BMPs required by the Everglades Regulatory Program, P loads from the surface water runoff attributable to the lands within the EAA basin have shown appreciable reductions. To interpret P measurements taken at inflow and outflow water control structures discharging from the EAA basin (**Figure 3-2**), it is important to recognize that water leaving the EAA basin through these structures is a combination of EAA farm and urban-generated runoff and water passing through the EAA basin canals from external basins. This "pass through" water includes discharges from Lake Okeechobee and from Chapter 298 water control district diversion areas (see Chapter 4A for a description of the diversion construction projects). Separate accounting of P loads from various sources is required to develop accurate conclusions about P loads originating from the EAA basin.

The reported P loads attributed to the farms, cities, and industries within the EAA basin should not be confused with the total P load being delivered to the Everglades. In fact, much of the flow leaving the EAA basin currently discharges to an STA for further treatment. With the completion of STA 3/4, all of the flow leaving the EAA basin will discharge to an STA prior to entering the Everglades. The accounting of tributary sources and flow configurations to the Everglades is complex. A comprehensive discussion of other sources and phosphorus loads discharged to the Everglades for WY02 can be found in Chapter 1.

The EFA specifically mandates a method to measure and calculate the annual EAA basin export of P in surface water runoff from the EAA lands (farms, cities, and industry). These calculations are adjusted for the hydrologic variability associated with rainfall and surface water discharges over time. These adjusted equations attempt to predict what the average annual total P load would have been for the EAA basin during the base period if the current water year's rainfall amount and monthly distribution had occurred during the base period. The calculations for the annual "percent reduction in phosphorus" are then determined simply as the relative difference between the measured annual loads and the corresponding predicted average annual base period loads.

EAA Basin Annual Phosphorus Measurements and Calculations

The first year of the 25 percent reduction compliance measurement mandated by statute occurred during Water Year 1996 (May 1995 through April 1996). Phosphorus load reduction measurements are conducted and reported annually. The EAA basin P loads and concentrations are determined in accordance with procedures specified in the Everglades Regulatory Program (Rule 40E-63) and the EFA. The data for all calculated years are summarized in **Tables 3-2** and **3-3**. The observed and predicted data for the EAA P calculations and annual rainfall and flow measurements are presented in **Table 3-3**. The P values presented are attributable only to the EAA basin (farms, cities, and industry) and do not represent the cumulative P being discharged to the Everglades from all sources. The data for WY02 are summarized below.

WY02, EAA total phosphorus load:

- Estimated P load from the EAA during the base period years, adjusted for WY02 rainfall amount and distribution (1979 to 1988) 227 tons
- Actual WY02 P load from the EAA with BMPs implemented 101 tons
- WY02 P load reduction (relative difference) 55%
- Three-year average P load reduction 59%

WY02, EAA phosphorus concentration (ppb)

- Actual annual average EAA P concentration prior to BMP implementation (1979 to 1991) 173 ppb
- Actual WY02 P concentration from the EAA with BMPs implemented 77 ppb
- Three-year flow-weighted mean P concentration 92 ppb

TABLE 3-2. Summary of EAA Basin P Calculations

TIME →

	WY80 ↓ WY91 Pre-BMPs	WY92 ↓ WY93	WY94	WY95	WY96	WY97	WY98	WY99	WY00	WY01	WY02
		Partial BMP Implementation*			Full BMP Implementation						
Three-Year Average Phosphorus Load %Reduction	**n/a**	**n/a**	**39%**	**36%**	**47%**	**51%**	**55%**	**44%**	**48%**	**57%**	**59%**
Phosphorus Concentration (ppb)	**173** 12-year average	**166** 2-year average	**121**	**130**	**109**	**106**	**100**	**107**	**114**	**107**	**92**
			3-year flow-weighted mean								
% Acres Implemented with BMPs per the Everglades BMP Program	0	0 *	15	63	100	100	100	100	100	100	100
WY Annual Phosphorus Concentration (ppb)	173 12-year average	166 2-year average	112	116	98	100	102	124	119	64	77
WY Annual Calculated Phosphorus Load % Reduction	n/a	n/a	17%	31%	68%	49%	34%	49%	55%	73%	55%
80% Confidence Interval in %	n/a	n/a	-26to46	-4to54	54to78	32to62	6to54	29to64	38to68	62to82	43to68

*NOTE: Lake Okeechobee SWIM BMP Program, 1992-1993, gave BMP credit for:

- Initiation of deep-well injection of domestic wastewater from Belle Glade, South Bay, and Pahokee
- Pump BMPs in S2 and S3 Basins

TABLE 3-3. WY80 through WY02 EAA basin total P measurements and calculations

Water Year	Observe TP (m. tons)	Predict TP (m. tons)	% TP Reduct.	Annual Rain (in)	Annual Flow (Kac-ft)	Base Period	Pre-BMP Period	LOK SWIM BMPs	Evrglds Rule BMPs
80	167	154	-9%	53.50	1162				
81	85	98	13%	35.05	550				
82	234	255	8%	46.65	781				
83	473	462	-2%	64.35	1965				
84	188	212	11%	49.83	980				
85	229	180	-27%	39.70	824				
86	197	240	18%	51.15	1059				
87	291	261	-12%	51.97	1286				
88	140	128	-9%	43.43	701				
89	183	274	33%	39.68	750				
90	121	120	-1%	40.14	552				
91	180	219	17%	50.37	707				
92	106	179	41%	47.61	908				
93	318	572	44%	61.69	1639				
94	132	160	17%	50.54	952				
95	268	388	31%	67.01	1878				
96	162	503	68%	56.86	1336	First Compliance Year			
97	122	240	49%	52.02	996				
98	161	244	34%	56.12	1276				
99	128	249	49%	43.42	833				
00	193	425	55%	57.51	1311				
01	52	195	73%	37.28	667				
02	101	227	55%	49.14	1071				

Note: The dashed vertical line indicates the period for which BMPs were not fully implemented.

Tables 3-3 through **3-7** represent the data graphically. Each bar in **Figure 3-3** represents the percent P load reduction for each water year including the base period years. In **Figure 3-4** each bar represents the actual measured (observed) annual P tonnage from the EAA basin in each water year and the line represents the annual phosphorus tonnage predicted by the rule-mandated methodology. The annual percent reduction of TP is calculated as the relative difference between the actual measured (bar) EAA basin P load and the predicted (line) base period P load (adjusted for rainfall). The EAA basin percent P load reduction trend is presented in **Figure 3-5**. The solid line shows the three-year trend of percent reduction. The ♦ symbols represent the annual measurements. An upward trend in the solid line in **Figure 3-5** denotes a reduction in loads, that is, an improvement in the water quality of EAA discharges. **Figure 3-6** shows the cumulative observed load reduction as well as the cumulative EFA mandated 25% reduction. As this chart indicates, the EAA basin has out performed its mandated goal. In the 7 years the program has been fully implemented over 1,100 metric tons of phosphorus has been removed compared to what would have been expected under the same hydrologic conditions during the base period. This compares to the mandated cumulative reduction of just over 500 metric tons.

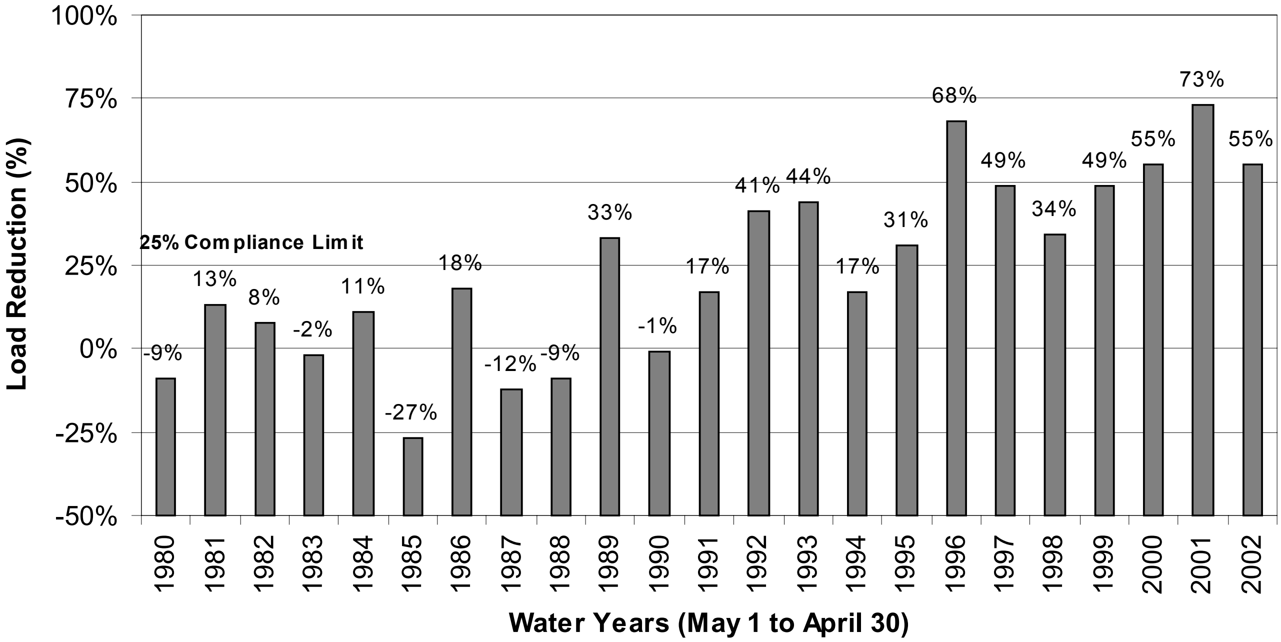

Figure 3-3. EAA basin total phosphorus percentage reduction

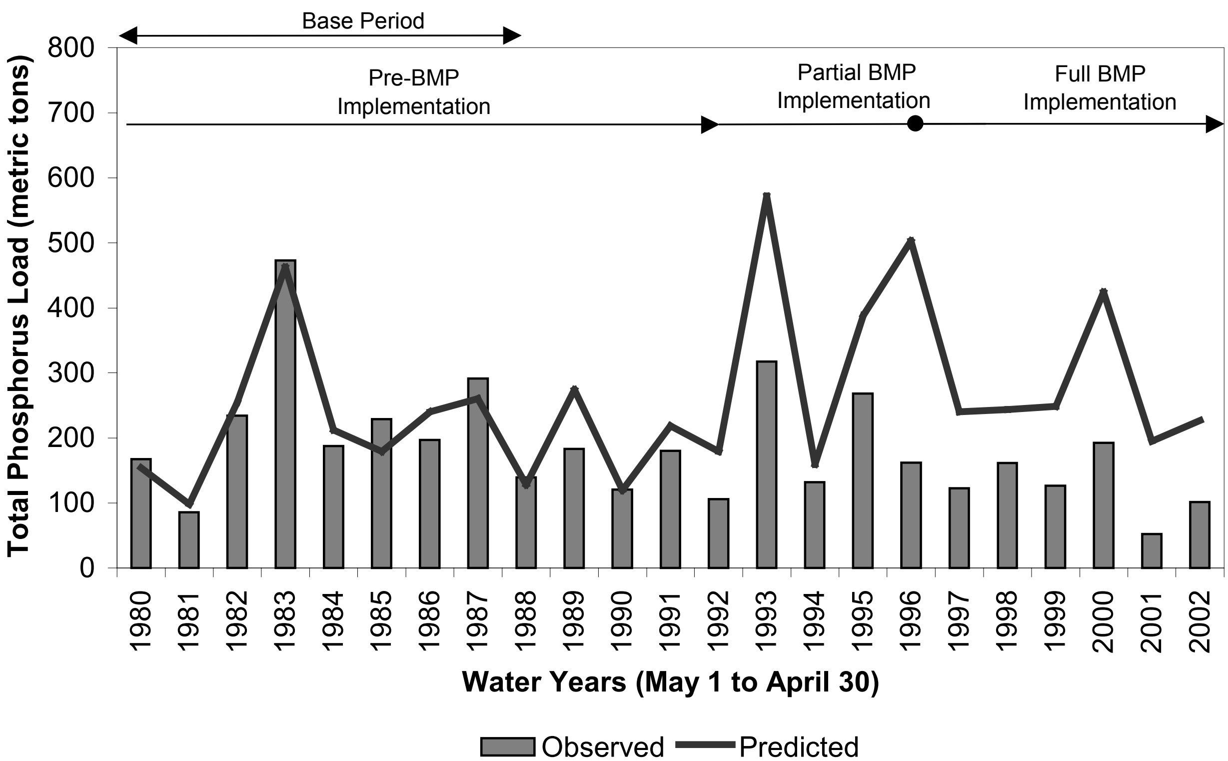

Figure 3-4. EAA basin TP load calculated

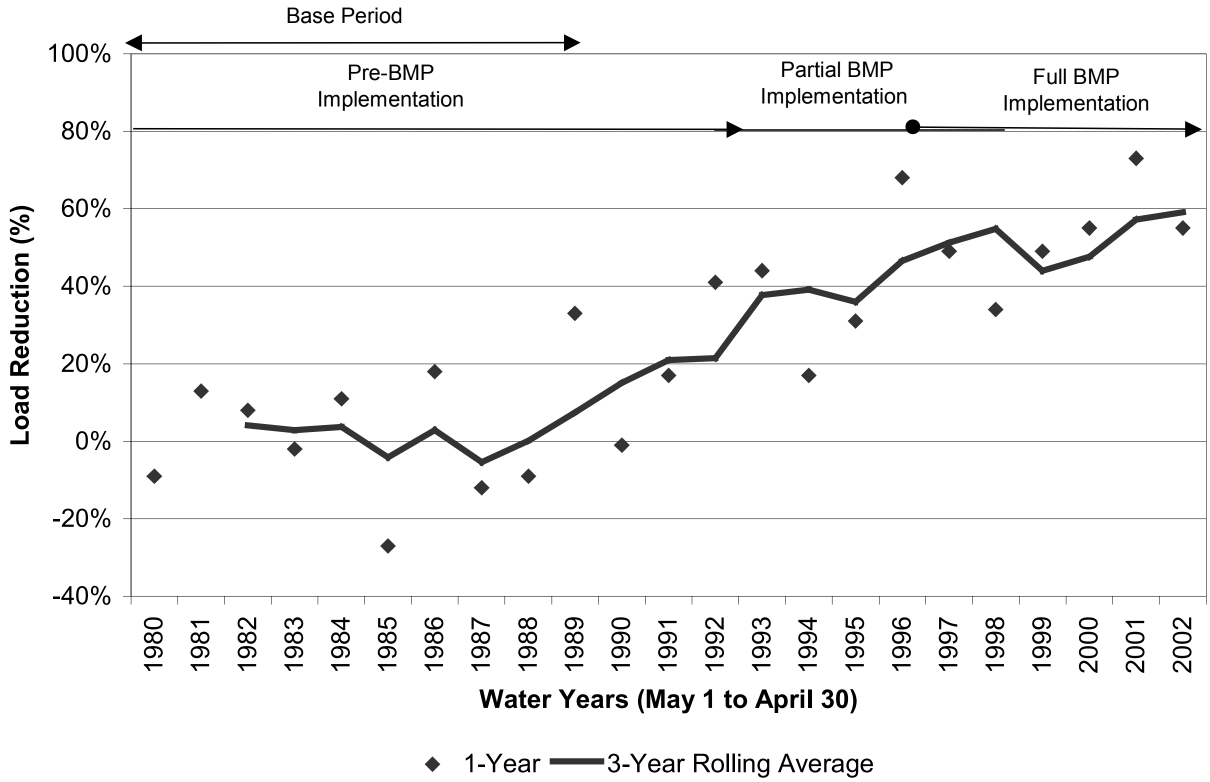

Figure 3-5. EAA basin percent TP load reduction trend

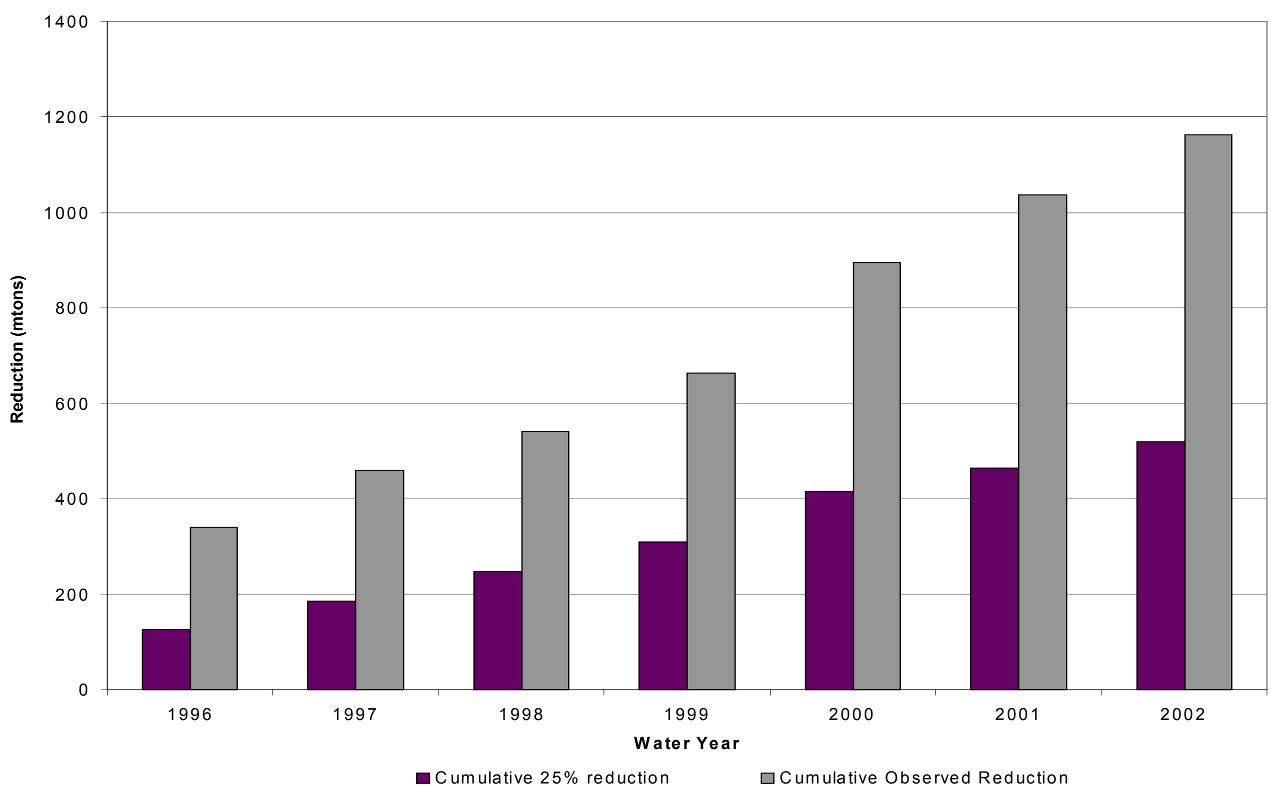

Figure 3-6. EAA basin cumulative percent P load reductions

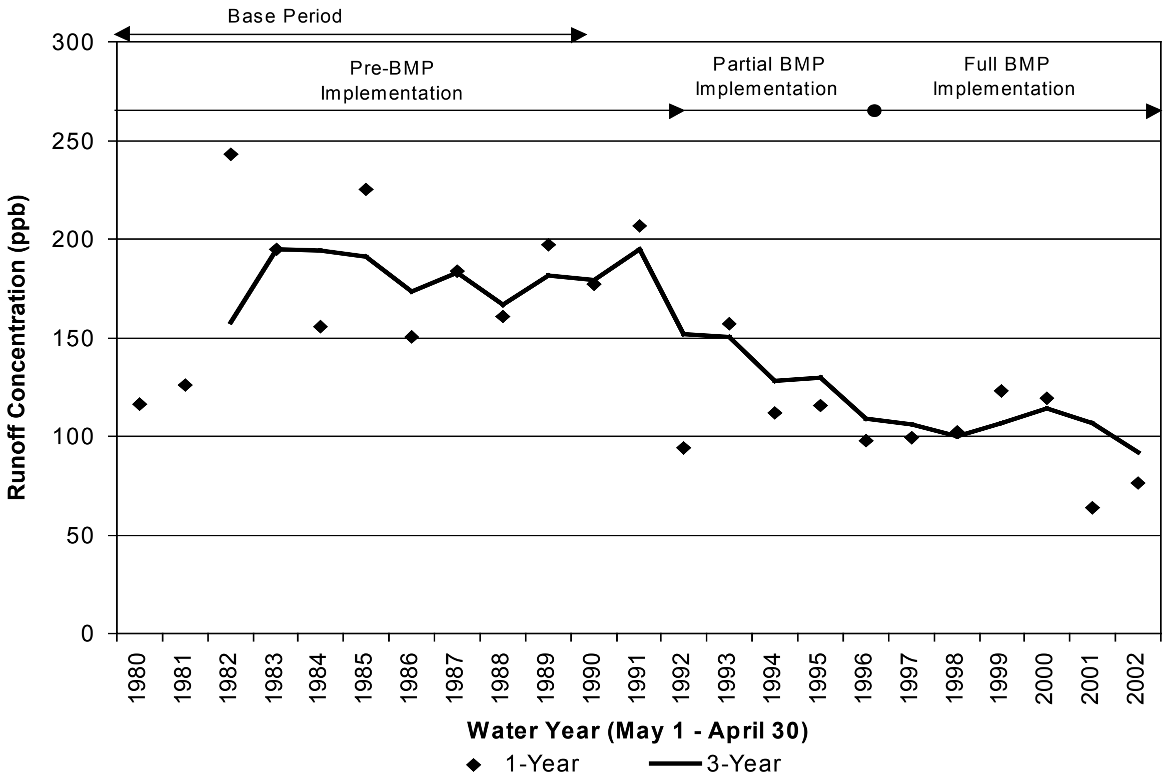

Figure 3-7. EAA basin phosphorus concentration trends

Phosphorus concentrations are calculated in addition to P load. Concentration levels, however, are not directly considered in determining EAA basin compliance, but flow-weighted concentrations do allow relative comparisons between years. Annual concentrations and three-year trends presented in the *2003 Everglades Consolidated Report* are true "annual flow-weighted" values calculated by dividing the total annual cumulative P load by the total annual cumulative flow. **Figure 3-7** shows the P concentration trends for the EAA discharges.

EAA PERMIT-LEVEL MONITORING RESULTS

In addition to the BMP Plan, each Rule 40E-63 EAA permit is required to propose a Water Quality Monitoring Plan for individual drainage basins within the permit. The permit-level monitoring plans consist of flow measurements, collection and compositing of discharge water samples, and analysis for total P. Discharges are generally quantified using site-specific calibration equations. Water quality samples are generally collected daily during discharge by automatic flow-weighted samplers and are composited for a sampling period of up to 21 days prior to being transported to a laboratory for analysis. Daily total P load is calculated by multiplying the TP concentration for the sampling period by each daily flow. Rule 40E-63 requires data to be submitted in an electronic format. Water quality samples are collected under a Comprehensive Quality Assurance Manual in accordance with FDEP requirements. In addition, any laboratory that analyzes TP for the Rule 40E-63 permit monitoring program is required to be certified by the Florida Department of Public Health for the analysis of TP in surface water.

Annual average flow-weighted TP concentrations (ppb) and load discharges (lb/ac) have been calculated from permittees' daily water quality monitoring data reported during WY02. **Figures 3-8** and **3-9** present frequency distributions of WY02 permittees' drainage basin P loads and concentrations, respectively. **Appendix 3-1** presents WY02 data in tabular form and as spatial distributions of P loads and concentrations discharged by permit drainage basins. The EAA basin-level data verify that the individual farms have collectively reduced phosphorus loads coincident with BMP implementation. However, the data collected so far do not establish a direct statistical relationship between the water quality and flow data from an individual EAA farm or subset of farms and the EAA basin as a whole. In fact, the permittee-level water quality monitoring cannot be used to determine the measure of phosphorus discharged to the Everglades. This conclusion is based on the fact that the average annual cumulative total volume of water discharged from the 300+ permittee or farm-level pump stations is greater than the volume released from the District water control structures surrounding the EAA. Additionally, EAA basin canal water (including rainfall and Lake Okeechobee discharges) and the surface water discharged from any one of the given 200+ defined permittee drainage sub-basins (farms) may be drawn back into the farm for irrigation or freeze protection by another farm. Each year a tremendous amount of water is recycled in this manner within the EAA prior to discharge to the Everglades.

There are also several factors affecting phosphorus load at the farm level, making it difficult to make comparisons and draw conclusions on differences in the level of performance between farms. UF/IFAS studies, discussed later in this chapter, make the point that each farm has a characteristic "lowest achievable discharge P concentration" that cannot be realized without an extensive implementation period and a substantial financial impact. Consideration must also be given to the minimum P required to support the agricultural production of specific crops. These factors are sometimes beyond the control of the permittee and also create differences in BMP effectiveness between sites, preventing an "apples-to-apples" comparison. They include variations related to historic and existing land use, fertilizer practices, soil characteristics, hydrology, land area, and geographic location. Examples of variables affecting individual farms are:

1. Weather Patterns: Timing and distribution of rainfall can affect an individual farm load. The model used to calculate the rainfall-adjusted unit area load for an individual permittee farm is dependent on District rainfall data collected for each Works of the District (WOD) sub-basin (e.g. S-5A, S-6, S-7, S-8) within the EAA. Adjacent farms can be located in different WOD sub-basins, and therefore have a significantly different rainfall adjustment.

2. Cropping Patterns: The history of cropping patterns on a farm can affect loads by creating a phosphorus "sink" or accumulation. The implementation of nutrient application control BMPs should correct this situation over time.
3. Hydrology: The hydrology of a farm affects loads in many ways. Examples include the size of the farm relative to the discharge pump capacity, or the effects of seepage from an adjacent Stormwater Treatment Area. Gradually, older pumps are being rebuilt or replaced to improve the capacity relationship between the farm area and the pump capacity.
4. Soil Characteristics: Soil depth and composition can also have a significant impact on a farm's performance. A farm may have high levels of calcium carbonate present in its soil, resulting in a high soil pH and precipitation of phosphorus. An adjacent farm may have much lower levels of calcium carbonate present in its soil and a lower soil pH.

These are examples of how each farm is unique, with BMP selection and effectiveness dependent on many factors. Permittees recognize unique effects on their farms and voluntarily make adjustments to operations and monitor the effects of these adjustments on water quality. Many of these adjustments require capital improvements that are phased in over time. For example, installing culverts to improve internal drainage to minimize discharges on a 20,000-acre farm could be an eight-year long project.

Permit-level data are useful for making relative comparisons between farms or between water years for the same farm, as long as they are used in conjunction with knowledge of unique farm characteristics. The District currently uses such relative comparisons when discussing individual farm performance and BMP optimization with permittees.

In accordance with Rule 40E-63, this on-farm, or permittee level water quality monitoring will only be used for compliance determination if the EAA basin does not meet the 25 percent phosphorus load reduction requirement. The permittee water quality monitoring results are not used to calculate the phosphorus reduction at the EAA basin level. The District currently conducts EAA basin level monitoring at all inflow and outflow structures for this purpose.

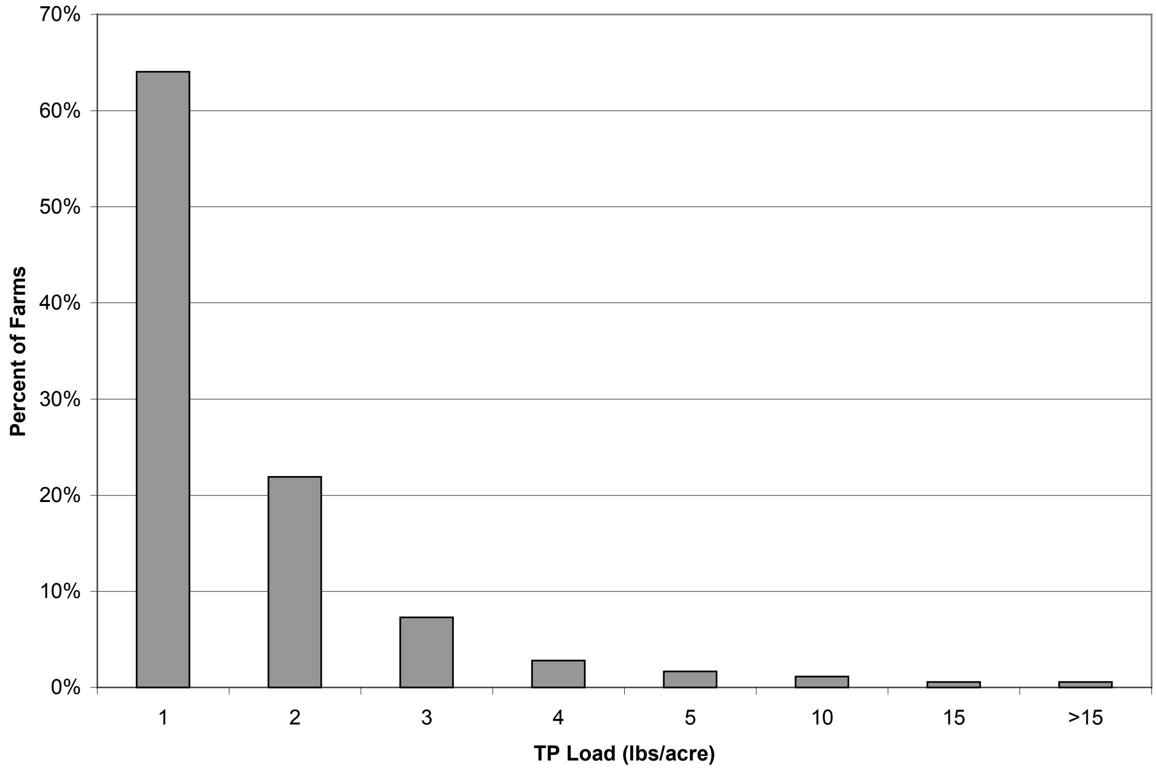

Figure 3-8. Permit level TP load frequency distribution

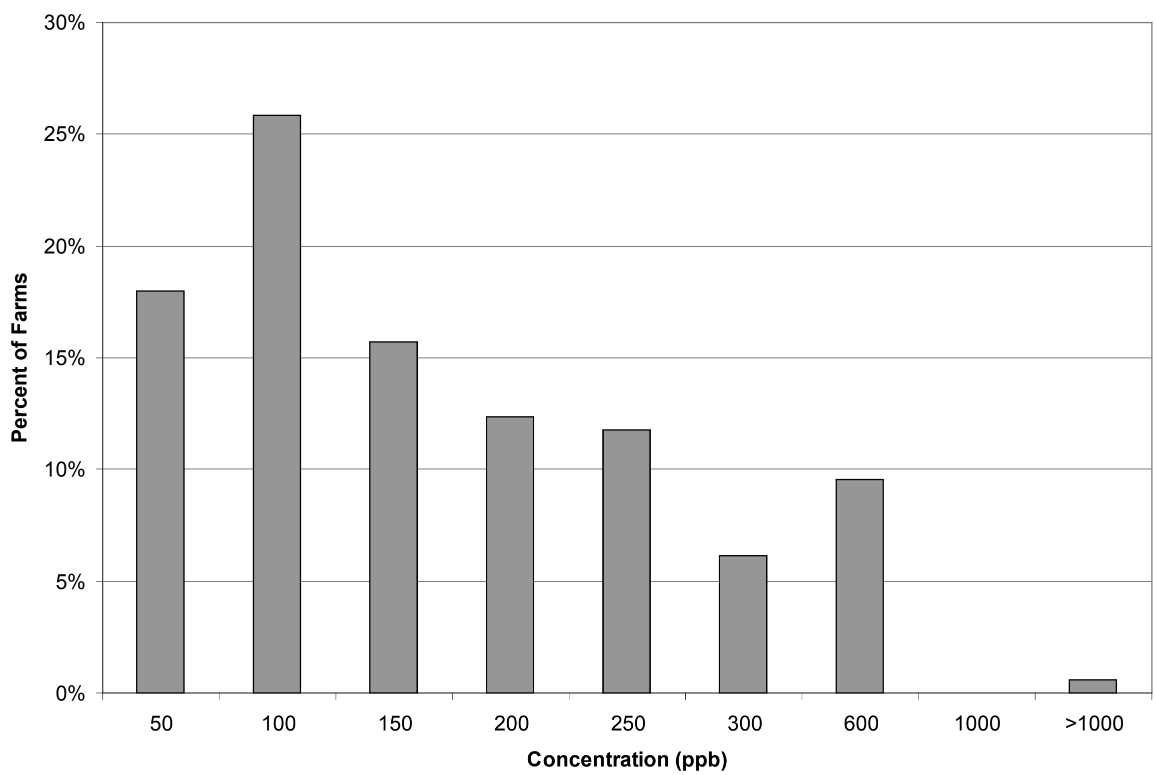

Figure 3-9. Permit level TP concentration frequency

UPDATE ON EVERGLADES BMP RESEARCH

BMP effectiveness has been demonstrated at different scales – in the EAA basin as a whole and through individual sub-basin or farm-level research projects in the EAA basin. In addition to BMP implementation, the EFA mandates landowners to sponsor a program of BMP research, testing, and implementation. Research projects to quantify BMP effectiveness are necessary to improve the understanding and predictability of TP relative to BMPs. To encourage BMP optimization as data become available, research results are provided to the industry through outreach programs sponsored by UF/IFAS, EAA-EPD, and the District. The following is an update on active BMP research projects in the EAA.

UNIVERSITY OF FLORIDA/INSTITUTE OF FOOD AND AGRICULTURAL SCIENCE (UF/IFAS) ON-FARM RESEARCH

The research conducted by UF/IFAS represents the most comprehensive ongoing research program regarding BMP effectiveness in the EAA basin. The project, initiated in 1992, was funded primarily by the EAA-EPD, with supplemental monetary contributions from the FDEP and the District. Ten farms ranging in size from approximately 320 acres to 4,600 acres have been studied in an attempt to develop and verify the effectiveness of BMPs for reducing P loading in the EAA basin. These farms are representative of the EAA basin with respect to soils, crops, water, fertilizer management practices and geographic locations. Land use on the selected farms varies from monocultures of sugarcane and vegetables to multi-cultures of vegetables, rice, sod, and sugarcane.

In earlier phases, the objective of the research was to implement and assess the effectiveness of BMPs in the EAA through a monitoring program and maintain a continuous database on drainage flows, cropping patterns, and water quality for sites representative of typical EAA farms. Other EAA BMP related efforts have since been incorporated into the project. They are as follows: identification of short-term and long-term affects of BMPs on soils and crops; evaluation of specific conductance and total dissolved P in farm discharges; and evaluation of particulate matter in farm and EAA drainage canals.

With regard to BMP efficacy, the research results have shown that both water management and crop rotation BMPs potentially have the greatest impact on P loads and concentrations of farm discharges. Water management practices that proved most effective included making internal drainage improvements to the farm to allow more uniform drainage. For example, a farm could be hydraulically subdivided into different blocks with internal water control structures. This practice makes it less likely that the farm will be over-drained and allows higher P water from areas within the farm to be recirculated internally. This practice works particularly well for farms that employ crop rotation practices. The study indicated that water table response and levels, i.e. drainage on the farm, are more heavily influenced by prevailing water table elevations rather than open channel gradients from pump operation. Therefore, a combination of improved drainage uniformity over the farm area and a reduction in drainage from a farm through internal re-distribution could significantly reduce P concentrations and loads for all crops.

Demonstration of short- and long-term effects of BMPs on soils and crops is being evaluated through a lysimeter study. A sugarcane lysimeter study was designed to demonstrate the effects of higher water table elevations on three sugar cane cultivars commonly used in the EAA, as well as the affects of re-distributing nutrient-rich drainage waters to sugarcane fields. A vegetable/rice lysimeter study was designed to demonstrate trends in soil fertility and crop nutrient uptake for different crop rotations, e.g. vegetable, rice, and flooded fallow. At this time final data analyses are being conducted. The results will allow determination of water use trends for all cropping systems. A final report is expected to be completed in 2003.

The evaluation of both specific conductance and total dissolved P is underway for monitored farm discharges. The purpose of the study was to identify causes for fluctuations in specific conductance and quantify the components of the total dissolved P. So far, there is insufficient data on specific conductance to draw conclusions. Further study of specific ions and how they relate to farming practices in the EAA will be necessary. The hypothesis is that agricultural practices, changes in hydrology occurring throughout the EAA, and connate seawater are contributing factors to the cause of elevated levels of specific conductance. However, the majority of the data collected on the research farms have fallen within class III water quality standards, that is, less than 50% above background or less than 1275 mmhos/cm, whichever is less. There are insufficient data to determine whether any of the implemented BMPs independently affect specific conductance; however, it is probable that P load reduction BMPs are helping to mitigate specific conductance issues that may relate to agricultural practices. Additional data and analyses are necessary to support these suggestions.

Another monitoring aspect of the research project involved particulate P transport studies. The primary goals were to identify the sources and the mobility characteristics of particulate P on EAA farms, and included sampling farm discharges for total P and total dissolved P. Particulate P was then calculated. Results indicate that approximately 50 percent of the total P in the farm discharge is attributable to particulate P. Furthermore, the P content of the particulate found in the farm discharge samples was significantly higher than the P content of the EAA soils. It was also found that the P content of floating macrophytes and their associated detritus in the EAA is significantly higher than the P content of farm soils. The study conclusion was that the primary source of exported particulate P in farm discharge is from biological growth in the main farm canal system.

The particulate P system is actually described in the study as a tri-modal population. The first particulate P population is very light and mobile and is readily re-suspended and transported under mild to moderate turbulent conditions. The second population included denser particulate that is more strongly associated with the underlying base sediment or the overlying aquatic weeds. This denser population requires a continued application of shear stress to erode it from the canal bottom or dislodge it from the overlying plants. High velocity flow can cause particulate P to be mobilized in large amounts. These two populations are the majority of the particulate P load and roughly correspond to the particulate exported during first flush and after continued high velocities. The third fraction of the tri-modal population of particulate P is randomly generated from localized concentrations of biomass or atypical hydraulic conditions, e.g. unusual rainfall events, canal level, or pump operating circumstances.

BMPs recommended by the study to control particulate P in discharges included practices that reduced the first flush and minimized the occurrence of continued high velocities. The future focus of this area of research will be to investigate other practices to reduce P loads associated with particulate P, including aquatic weed uptake of P and the hydraulic redistribution of the plants and settled detritus.

These research projects confirm the effectiveness of existing BMPs, as well as provide direction on areas of future focus with continued data collection. A key component to the IFAS research goals is to promote the continued, uniform, and conscientious implementation and management of BMPs. This is accomplished through the IFAS extension program, consisting of numerous seminars, workshops, and publications offered to the EAA community.

FINDINGS AND FUTURE DIRECTIONS

The overall effectiveness of BMPs is best demonstrated by the measured P load reduction in the EAA basin since BMPs were implemented, compared to a 10-year, pre-BMP base period. BMP effectiveness is further supported by ongoing BMP research in the EAA basin. The goal of the EAA's Everglades Regulatory Program is a 25 percent annual TP reduction from the EAA basin compared to the base period. Water Year 2002 represents the seventh year that the EAA basin has been in compliance with the required P load reduction requirement. The WY02-adjusted P load, assuming that BMPs were not implemented, was predicted as 227 tons. The measured total P load was 101 tons, resulting in a 55-percent reduction. The overall trend over several years has shown a significant reduction in P load since the implementation of BMPs. The annual TP concentration shows a similar reduction trend with the recent three-year flow-weighted mean of 92 ppb, compared to 173 ppb during the pre-BMP period.

The basin-level reductions are generally supported by the UF/IFAS on-farm research. However, variations between farms and years are significant, as indicated by the results of both the farm-level monitoring conducted by permittees and the UF/IFAS on-farm research.

Recent data continue to support the ongoing pursuit of past recommendations. That is, through continued research, monitoring, and education efforts, water quality improvements can be made by applying new information to existing situations and by applying lessons learned to other regions that discharge to the Everglades. Future BMP work should continue to be directed at:

1. Identifying other potential BMPs and their applicability to specific areas and water quality parameters
2. Optimizing the effectiveness of established BMPs
3. Promoting the BMP "message" through an aggressive education and outreach program

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